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Closing the energy-efficiency technology gap in European firms? Innovation and adoption of energy efficiency technologies

Wolfgang Gerstlberger[a,*], Mette Præst Knudsen[a], Bernhard Dachs[b], Marcus Schröter[c]

[a] Centre for Integrative Innovation Management, University of Southern Denmark, Department of Marketing & Management, Denmark
[b] AIT Austrian Institute of Technology, Austria
[c] Bochum University of Applied Sciences, Germany

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ABSTRACT

This article investigates the determinants of the adoption of energy efficiency technologies in European manufacturing firms and the role of product and process innovations in the adoption process. The empirical results show that product and process innovation are positively related to adoption of energy efficiency technologies. Moreover, there is a positive association between environmental performance measurement systems and adoption of the aforementioned technologies. Interestingly, product innovative firms are more likely to adopt additional energy efficiency technologies only if they have already introduced these technologies in the past.

1. Introduction

The European Union has an ambitious 'Green Agenda' through the year 2020 (European Commission, 2015a, b). The main topics on this Green Agenda are a more competitive, low-carbon economy and an efficient, sustainable use of resources. Goals include energy and materials production founded on a more circular economy, reduction of emissions, maintaining biodiversity, and strengthening of Europe's leadership in developing new green technologies and production methods.

To support this Green Agenda, governments have passed directives, laws, and ordinances to stimulate a change in industry towards higher efficiency with respect to energy consumption (Chan et al., 2010; International Energy Agency (IEA), 2011; Thollander et al., 2007, 2012). For instance, in 2012 the European Union passed a directive to promote energy efficiency as a means to reach a 20% reduction of the Union's energy use by 2020 (Article 3; European Parliament and European Council, 2012). The directive outlines a set of paths by which energy efficiency can lead to reduction in energy use, and includes implementation of specific energy efficiency technologies for manufacturing firms (Scheuer, 2013).

* Corresponding author.
E-mail address: woge@sam.sdu.dk (W. Gerstlberger).

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Even though firms are considered to be important drivers for achieving these goals, especially in the manufacturing sector, many European firms still pay limited attention to energy efficiency targets and requirements set out in such directives despite the fact that adherence would likely be profitable for them (Braungardt et al., 2014; Trianni et al., 2016). Jaffe and Stavins (1994) coined this phenomenon the 'energy-efficiency gap', which is defined as the difference between 'actual and optimal energy use' and is empirically identified in manufacturing firms. This gap can be explained at least partly by economic, organizational, or behavioral barriers preventing the adoption of energy efficiency technologies (EETs) at the firm level (Sorrell et al., 2000; Cagno et al., 2013).

In addition to taking into account these specific barriers preventing the adoption of energy efficiency technologies, it is also beneficial to extend the view to include an examination of the interactions between environmental innovation and adoption of EETs to understand the energy efficiency technology gap in European manufacturing firms. Adoption of energy efficiency technologies by firms is a means of achieving *direct* reductions in energy consumption for production and other activities. Furthermore, adoption and implementation of EETs are themselves innovative activities with *indirect effects,* e.g. facilitating knowledge sharing on production technologies at the firm level and supporting other innovative activities like organizational adaptations and developments. In our study we consider EETs to be one type of innovation area within the firm, with *indirect effects* that may cut across and include the development and introduction of new products, new production technologies, offering new services, or a novel approach to organize the internal processes of the firm (this is in line with Damanpour 1991, 556), who defined innovation as *the adoption of an internally generated or purchased device, system, policy, program, process, product, or service that is new to the adopting organization*.

Findings from recent quantitative studies (Rennings and Rammer, 2009; Hottenrott et al., 2012) suggest that an increased adoption of EETs is positively related to accompanying product, process, and certain types of organizational innovations such as environmental management systems. The reasons for this positive relation are not yet understood. However, knowledge spill-overs from process, product, and organizational innovations along with combined learning curve effects are discussed currently in the emerging eco-innovation literature as potential explanations (Veugelers, 2012; Dangelico, 2015; Iñigo and Albareda, 2016).

This article extends the discussion by investigating the relationships between adoption of energy efficiency technologies and other innovative activities to unravel their direct and indirect effects, and discusses how firms can reduce the energy-efficiency gap by accomplishing policy targets set out in the Green Agenda. Our research tests associations between adoption of energy efficiency technologies and different innovation types by utilizing data from the European Manufacturing Survey (EMS). This data set includes information from more than 2500 manufacturing firms from six European countries (Austria, Germany, Switzerland, Finland, the Netherlands, and Denmark) on their adoption of five distinct energy efficiency technologies.

The research contributes four main findings to the discussion of environmental innovation, using a unique methodological approach. First, the adoption of energy efficiency technologies is positively related to the adoption of other technical process innovations. Second, there is also a positive relationship between adopting EETs and organizational innovations such as environmental performance measurement systems. Third, firms which are particularly strong with technological competencies and in adoption of energy efficiency technologies are also likely to be product innovators. Fourth, the sector and the country of the firm matters for decisions about the adoption of EETs. To derive these findings, our methodology involves testing a specific measure in a way which combines 'hard' and 'soft' types of variables for measuring the adoption of energy efficiency technologies. We discuss these findings further in the remainder of this article and conclude with implications for managers.

2. Literature review

2.1. New agenda on environmental innovation

New forms of innovation increasingly appear in the debate about firms' future competitiveness, namely eco-innovation (Arundel and Kemp, 2009), environmental product innovation (Gerstlberger et al., 2014), sustainable innovation (Geels et al., 2008), or more recently green product innovation (GPI) (e.g. Dangelico, 2015). The different naming clearly demonstrates the complexity of delimiting and defining the content of environmental innovations. A complication in defining innovation activities with environmental impact is that it is insufficient to focus on products; rather, other types of innovation activities must be included. Damanpour (1991) demonstrated the existence of empirically distinguishable dimensions of innovation including administrative and technical innovations. Technical process innovations are broadly defined as new elements introduced into an organization's production or service operations, and equipment used to produce a product or render a service (following e.g. Utterback and Abernathy, 1975). In particular, Damanpour (1991) defined an innovation as *a new product or service, a new production process technology, a new structure or administrative system, or a new plan or program pertaining to organizational members. Thus, innovation is defined as adoption of an internally generated or purchased device, system, policy, program, process, product, or service that is new to the adopting organization* (Damanpour, 1991, 556). The current focus on environmental innovation in the academic literature emphasizes not only the adoption aspects of innovation, but also argues for a more systematic approach for understanding sustainable development and innovation (Boons et al., 2013; Amores-Salvadó et al., 2014; Bocken et al., 2014a, 2014b; Ghisetti et al., 2014; Wagner et al., 2014; Dangelico, 2015). Dangelico (2015) has recently presented an extensive literature review based on a framework that specifies